...creating new materials, solving global challenges...

Direct separation technology for capturing process CO2 emissions

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ECRA/Cemcap November 2017

Calix

Calix Flash Calcination…."CFC"

Calix Flash Calciner ("CFC"), Bacchus Marsh, Australia

CFC converts low value minerals to **high value materials** in a new and highly innovative way:

- low CO_2 footprint; capture and recovery of high purity gases

CFC produces "**Mineral Honeycomb**"

- micron-sized
- ultra-high surface area; nano-active and bio-active
- produced at a fraction of the cost vs. true nano-materials
- multiple disruptive applications in water, food, energy and infrastructure

Calix $MgCO_3$ Mine, Australia

Ore - $MgCO_3$

CO_2 Separation Australia

Nano-active - MgO

Satellite Hydration, (close to customer)

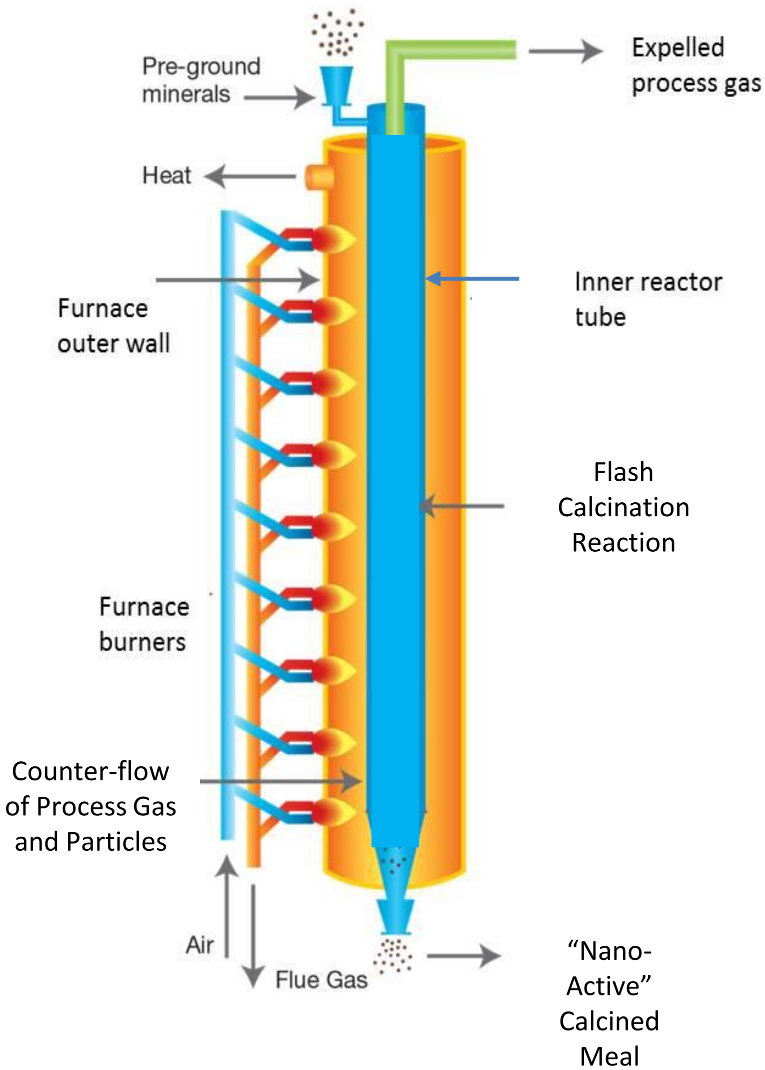
Product - $Mg(OH)_2$

Packaging and Distribution

Application Eg Rice, Philippines

Calix

Technology : "CFC"…Calix Flash Calcination



1. Isolation of kiln furnace gases from the calcined product…

The use of indirect heating allows for control of the calcining atmosphere (inert, reducing, oxidising) plus the efficient, direct capture of CO_2 from the processing of carbonates such as limestone.

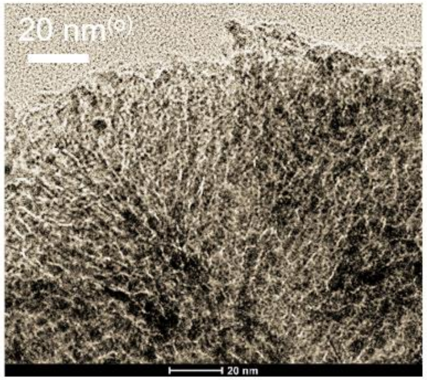
2. Calcination of micron-sized particles…

Through indirect (radiative) heating micron-sized particles in a "downer reactor" tube, far higher control and reactivity is achieved, as well as ultimate flexibility in feed (mineral) inputs by type and size.

3. Production of "nano-active" materials…

The combination of 1 and 2 is being used to produce new materials, proving to be "nano-active" in their properties while micron-sized in scale.

"we make mineral honeycomb"



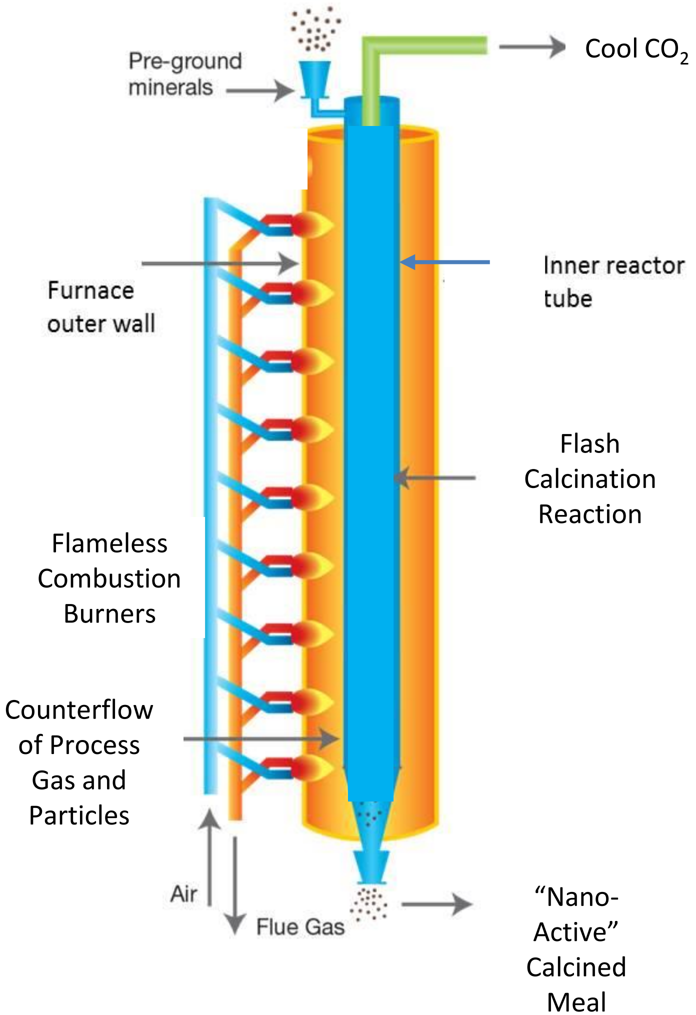
Low Emissions Intensity Lime & Cement

A European Union Horizon 2020 Research & Innovation Project

LEILAC Project Overview

November, 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465



The LEILAC (Low Emissions Intensity Lime And Cement) Project aims to apply and demonstrate a breakthrough technology that will enable Europe's cement and lime industries to reduce their emissions dramatically - at the same time as retaining their international competitiveness.

The Challenge:

- Around 60% of their total CO_2 emissions are unavoidable.
- CCS will need to be applied to the majority of European cement plant to meet the EU's emission reduction target
- The cement and lime industries are under intense competitive and cost pressures

The Concept:

Indirect heating raw meal:

- Direct capture of process-related CO_2
- 95% capture rate of pure CO_2

Planned pilot plant in Lixhe, Belgium

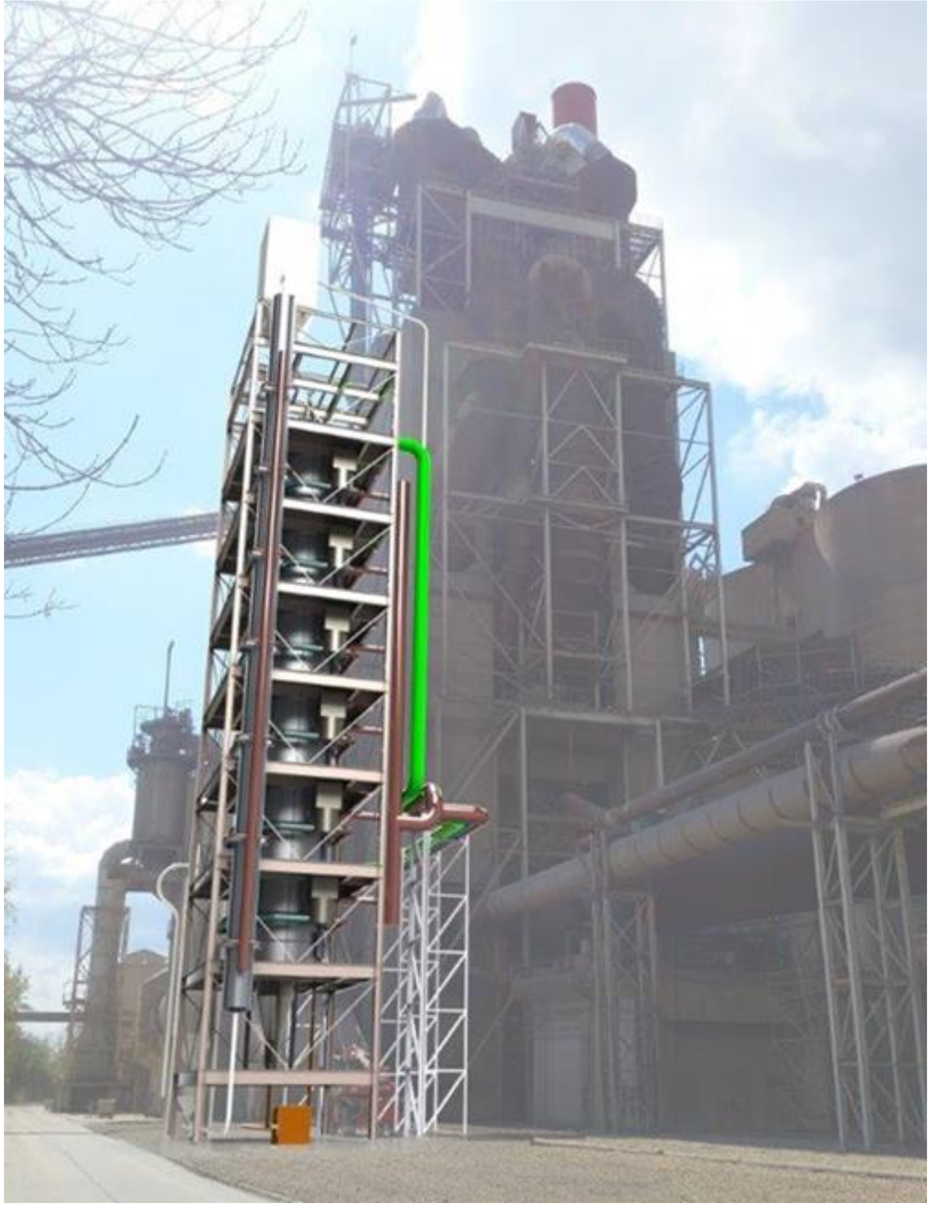
- Lime application 8tph
- Cement application 10tph

€12m H2020 grant plus € 9m in-kind

- 5-year project, start in 2016
- Commissioning from late 2018

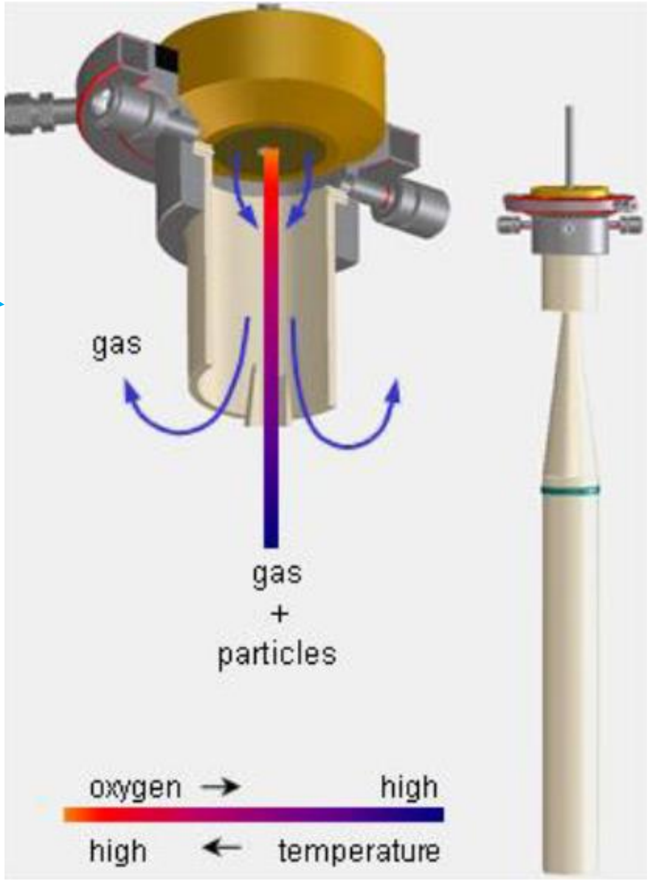
Major challenges and barriers

- Scale-up of temperature.
- Corrosion and scale formation.
- Calcination level and throughput.
- Capital cost of the pilot.
- Future scale-up and integration.



Metals Testing at ECN

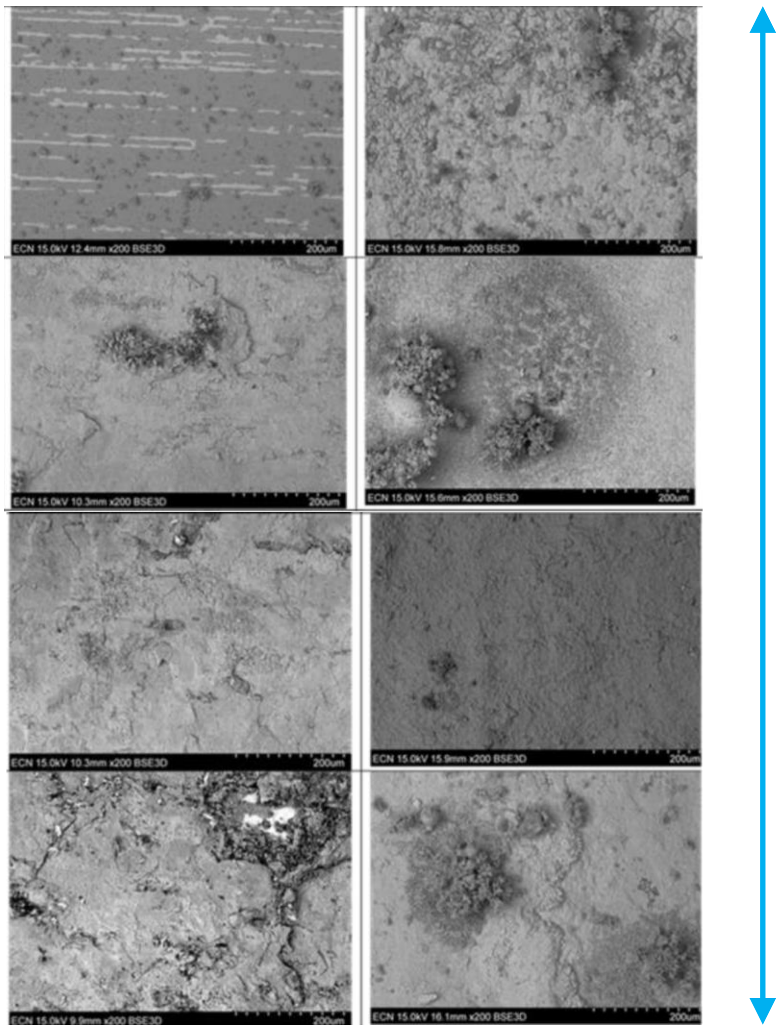
- Key risk: stability of the chosen steel at temperatures of interest (up to 1000 °C)
- Tested using LCS:
  - 250 h
  - 86% CO_2, 14% H_2O (and 0.1% O_2)
  - 970 – 1025 °C
  - 3 g/h solids – Lixhe kiln feed
- Tested using autoclave
  - > 1000 hrs planned
  - 86% CO_2, 14% H_2O (and 0.1% O_2)
  - 950 – 1050 °C
  - No solids
- Extensive XRF studies



ECN's Lab-scale Combustion and Gasification Simulator (LCS)

Metals Testing at ECN

Outer (flame) **Inner (DS)** **Top**



- Oxide layer on inner = 5-8 μm
- Oxide layer on outer = 3 μm (though larger towards bottom)
- More particle deposition on inner side
- More spalling and oxide separation on inner side

Conclusions:

- Growth on surface through adhesion of CaO particles on the surface
- Adhesion can induce corrosion/solid state transfer of Cl and S species
- Detachment of particles can expose bare metal

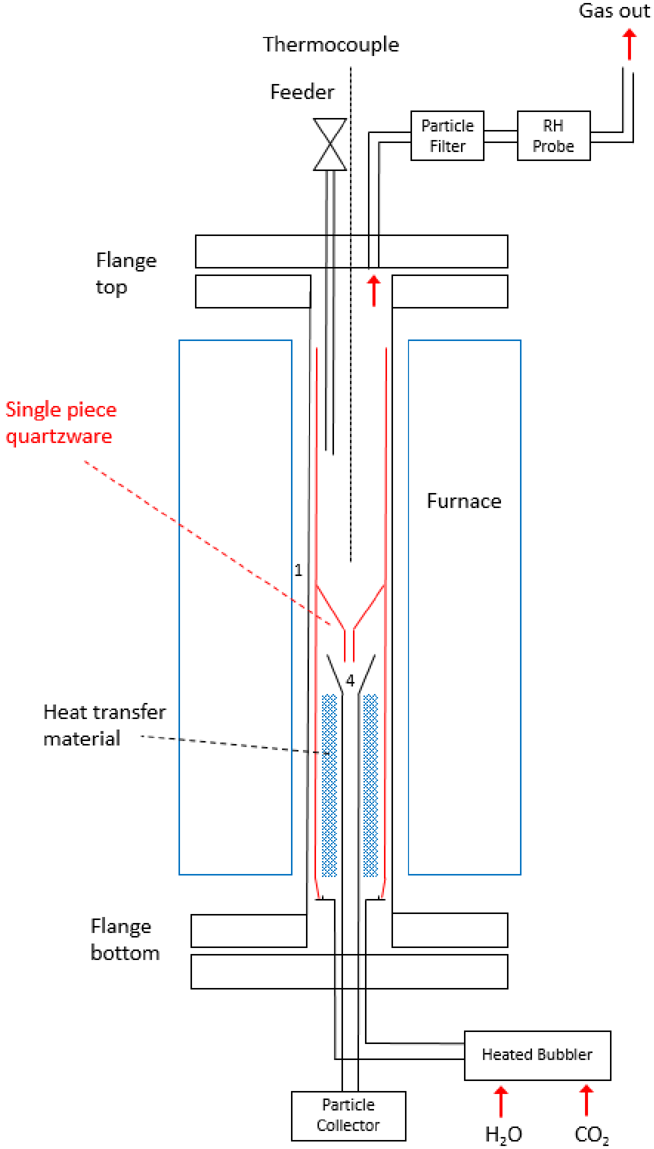
Investigating use of magnesite to generate Mg-Si phase layer to make steel resistant to CaO attack

Imperial College Overview

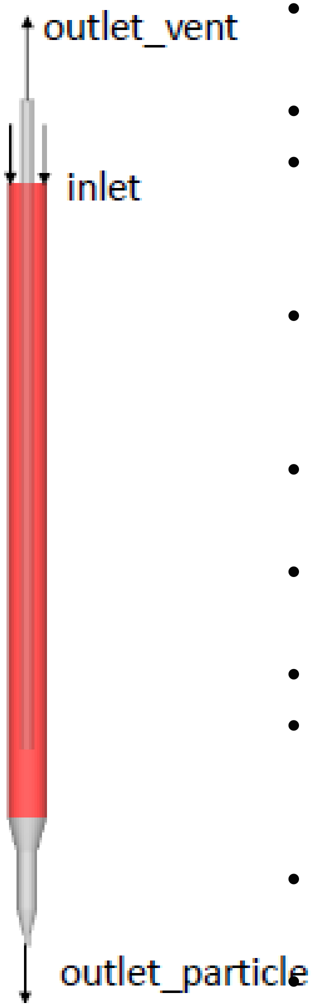
Imperial College are active in several R&D tasks contributing to LEILAC pre-FEED and FEED periods

Key involvement:

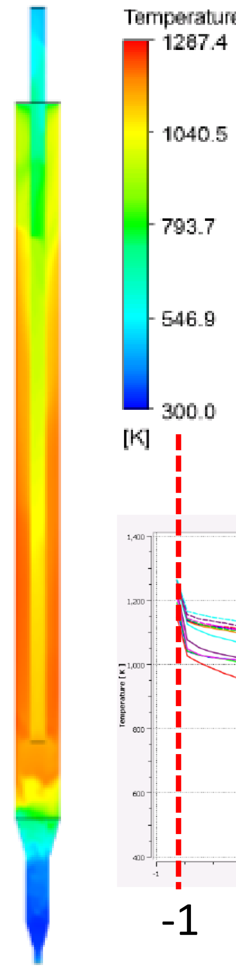
- Investigation of kinetics of calcination and re-carbonation in a steam environment; including commissioning of suspension reactor
- Product evaluation, i.e., the suitability of test products for use in cement and lime industries, using appropriate in-house test methods
- Modelling of radiative heat transfer and CFD in the Direct Separation reactor with Cemex

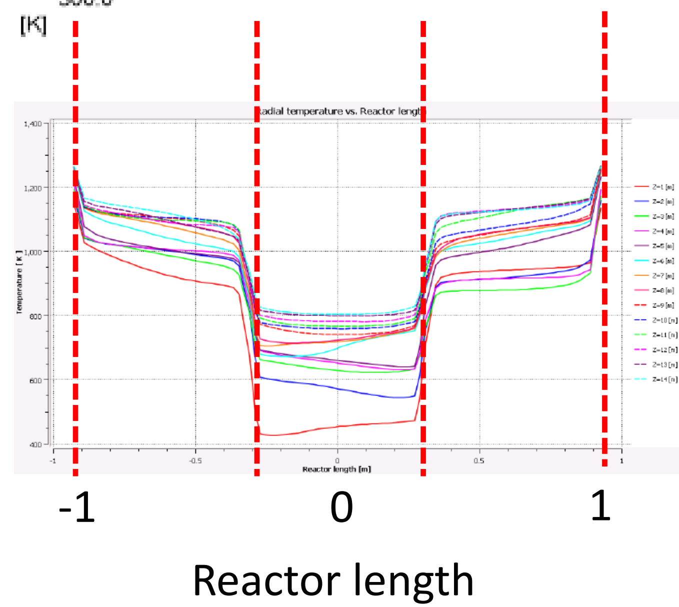


CFD at Imperial College



- Objective: to model pipe section of reactor
- ANSYS Fluent CFD
- Inlet conditions and design kept as close to early design of Leilac reactor as possible
- Original CO_2 vent modelled alongside calcining particles; not outer heating gas
- Structure mesh with hexahedral elements, total = 1.4m
- Wall, two layers shell mesh, total = 66k
- Max aspect ratio < 16
- Euler-Lagrange approach was taken, including discrete particle and turbulent flow models
- Preliminary results shown – reaction not included
- Validated counterflow trials in Australia

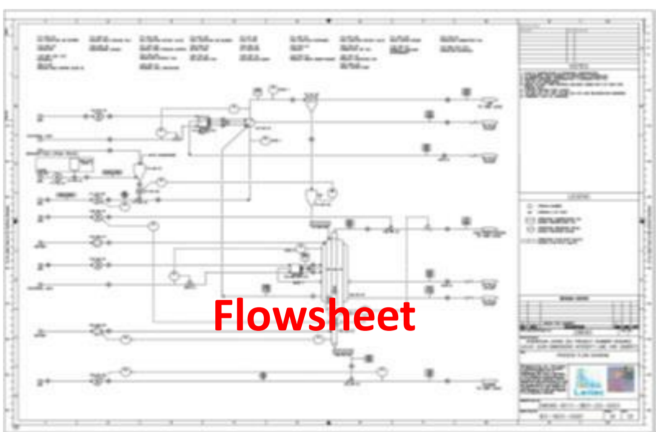


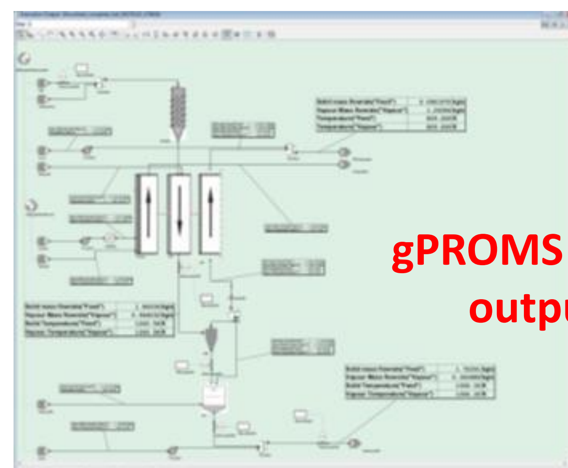


Process Modelling at PSE

1. Developed benchmarks for cement and lime with and without CO_2 capture to assess LEILAC performance
2. Transferred heat transfer and kinetics models to gPROMS advanced modelling platform, enabling additional process integration and optimization
3. Built and validated process model of the LEILAC pilot plant
4. Design criteria exceed target outputs

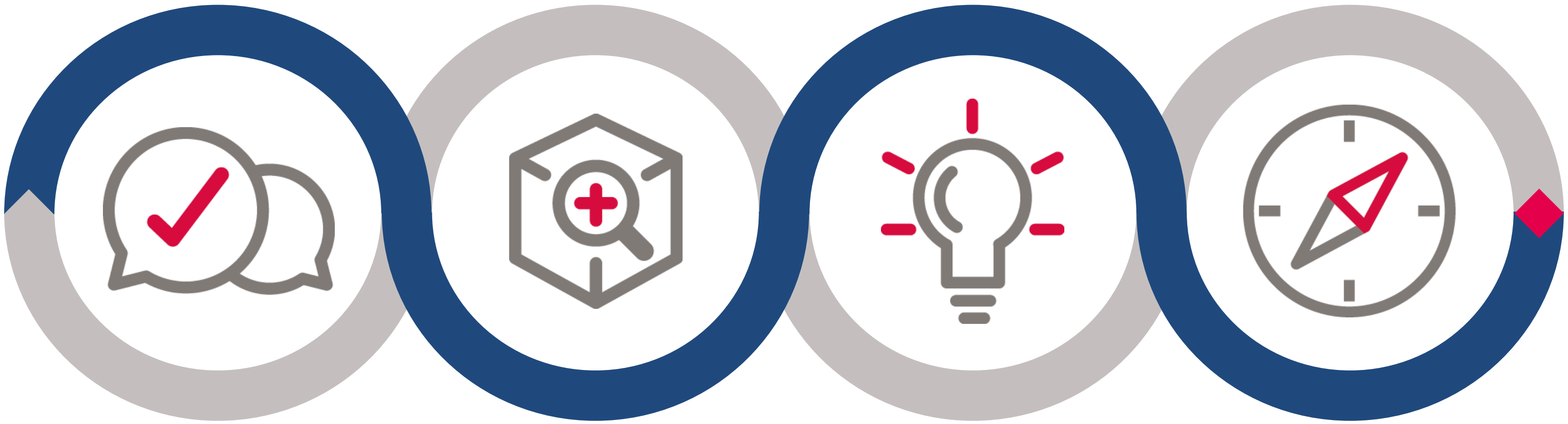
Benchmark technologies	
Cement (Dry)	**Lime**
5000 ton per day clinker production	600 ton per day lime production
6250 ton per day cement production	Parralel flow regenerative kiln
5 preheat stages	Natural gas fuel
Validated with partners' baseline flowsheets	





gPROMS output

Life Cycle Assessment at Quantis



Model in Simapro 8.3.0

Database ecoinvent v3.3

IMPACT2002+ methodology impact assessment

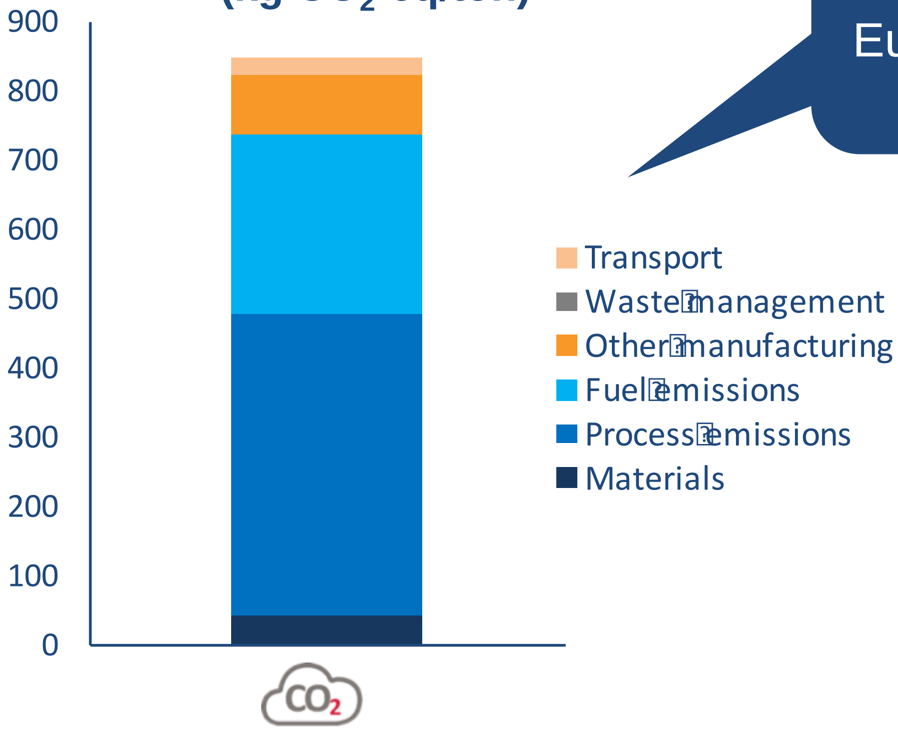
Input data from CSI, EuLA, LEILAC, BREF reports, etc.

- Cradle-to-gate assessment, including raw materials extraction, processing
- Comprehensive investigation of Direct Separation benefits
- Comparison to conventional plants and current carbon capture technologies

- Focus on the following indicators:
  - GHG emissions (carbon footprint)
  - Non-renewable primary energy use (energy footprint)
  - Water use (water footprint)
  - Impacts on human health
  - Impacts on the ecosystem

Life Cycle Assessment at Quantis

Preliminary carbon footprint of 1 ton of cement produced in Europe ($kg\ CO_2$-eq/ton)



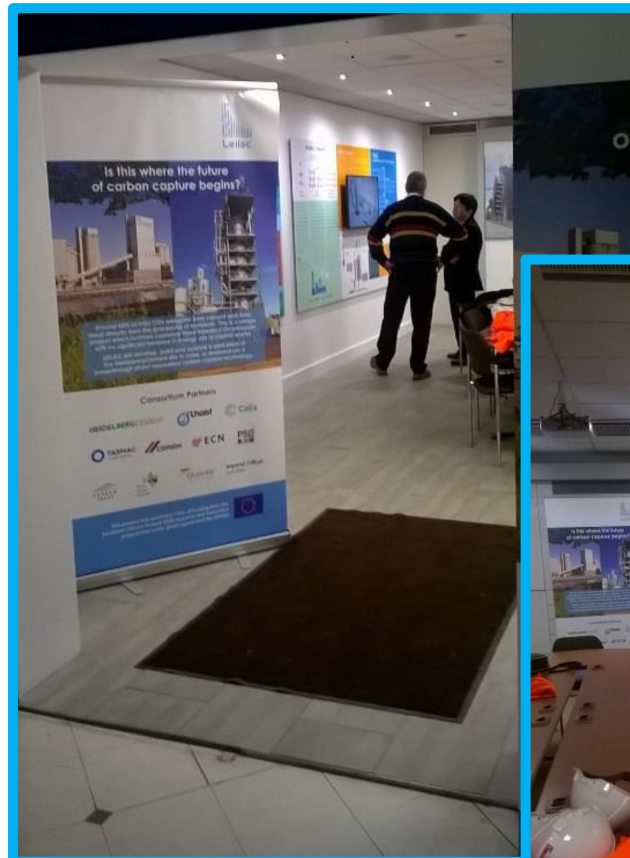
The LEILAC technology environmental footprint will be compared to average European production and best available technology for cement and lime

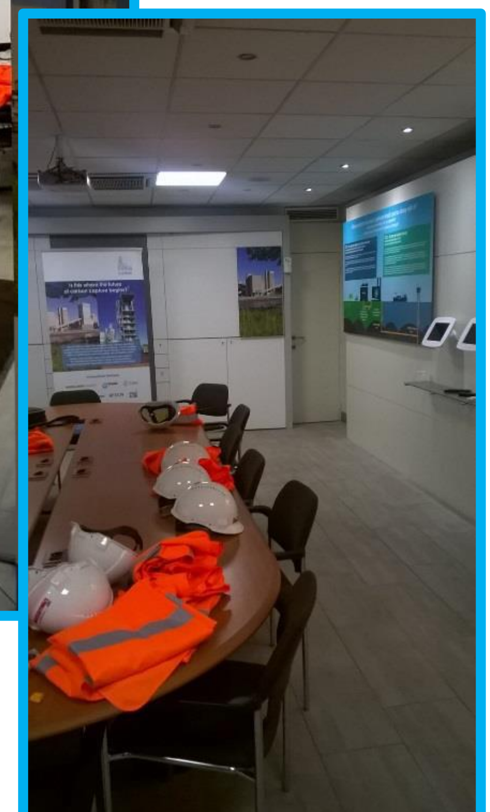
Process and fuel emissions during the clinker production represent **82%** of the total carbon footprint of cement

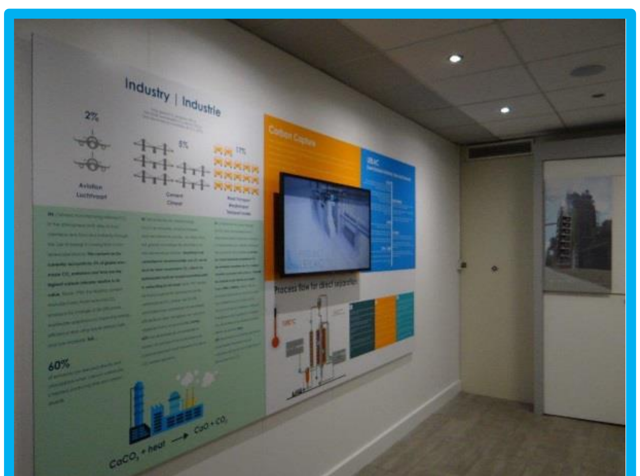
Results from the Cement Sustainability Initiative's EPD Tool for cement and concrete, developed by Quantis | European average cement

Communication Strategy at Carbon Trust

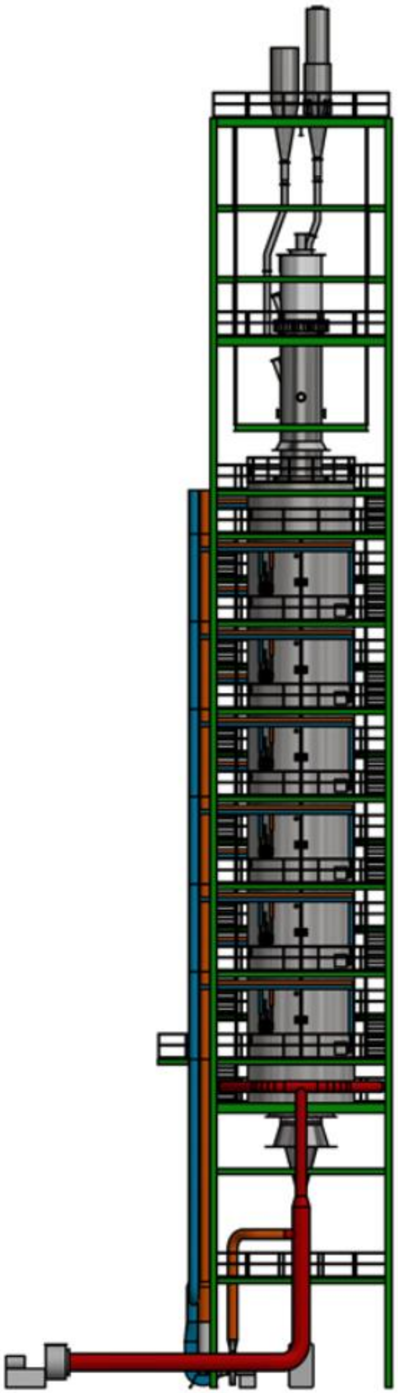
- **Come visit us!**
- Visitor Centre at Heidelberg Lixhe site and is open for duration of project
- Targeted at specialists and non-specialists alike
- Exhibits translated into 3 languages







Leilac



Expected impact

Output

- A pure CO_2 stream
- 5 to 10 times more reactive product

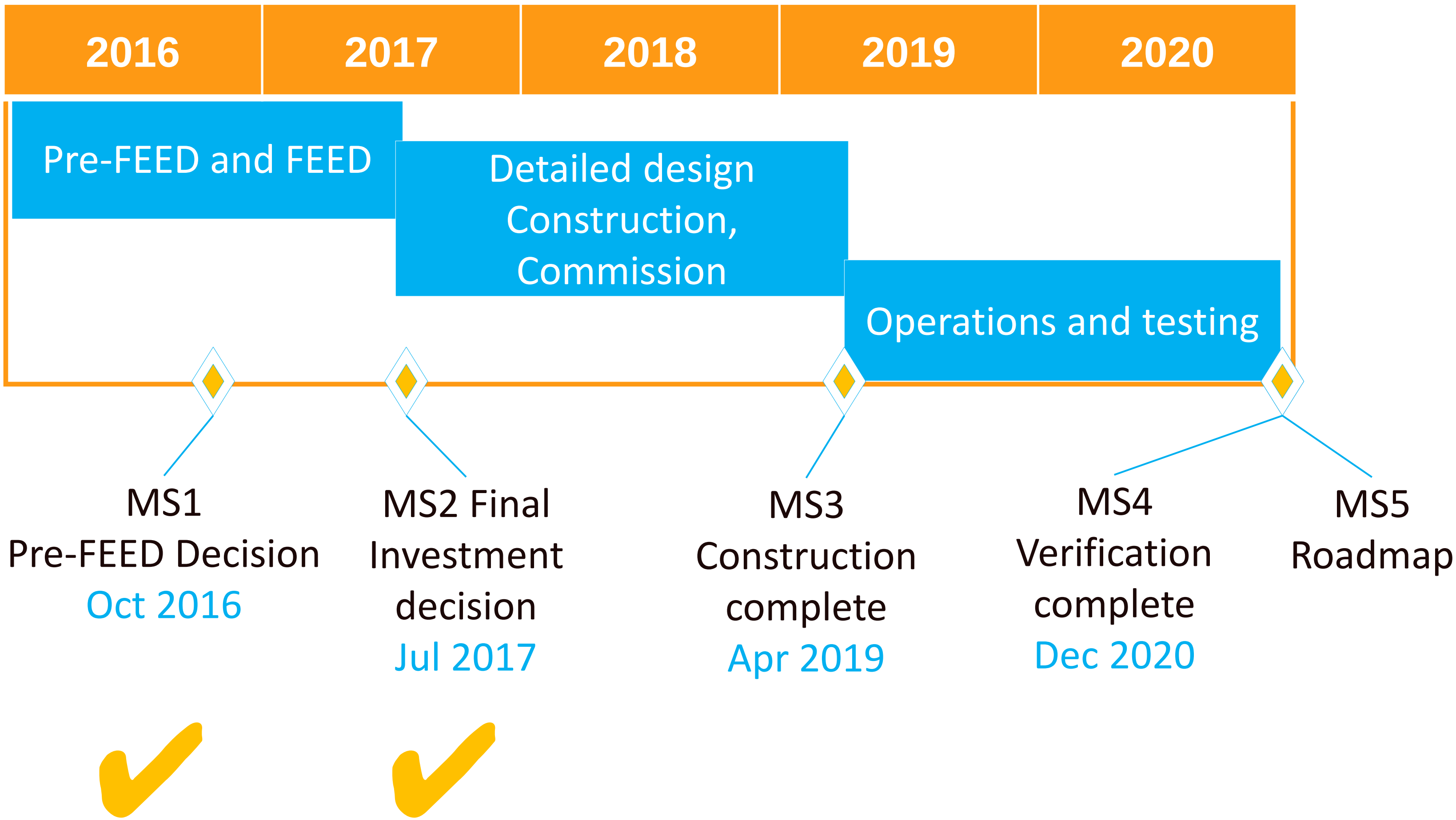
Features

- Retrofit (replaces existing calciner) or new-build
- Can be built to handle variable mineral input streams
- Can use a variety of fuels: gas, electricity, and (with a gasifier) biomass, waste and coal.
- Accurately controlled temperature and reactor residence time minimises sintering (loss of activity)
- Can handle fines that cannot be processed by conventional lime kilns, but appropriate for cement meal and limestone fines.
- Enhances other CO_2 abatement technologies (e.g. oxyfuel firing) and alternative fuels.

Cost

- Captures process CO_2 for no energy penalty (just compression).
- Comparable capital costs + potentially lower operating and maintenance costs to conventional kilns

LEILAC project timeline

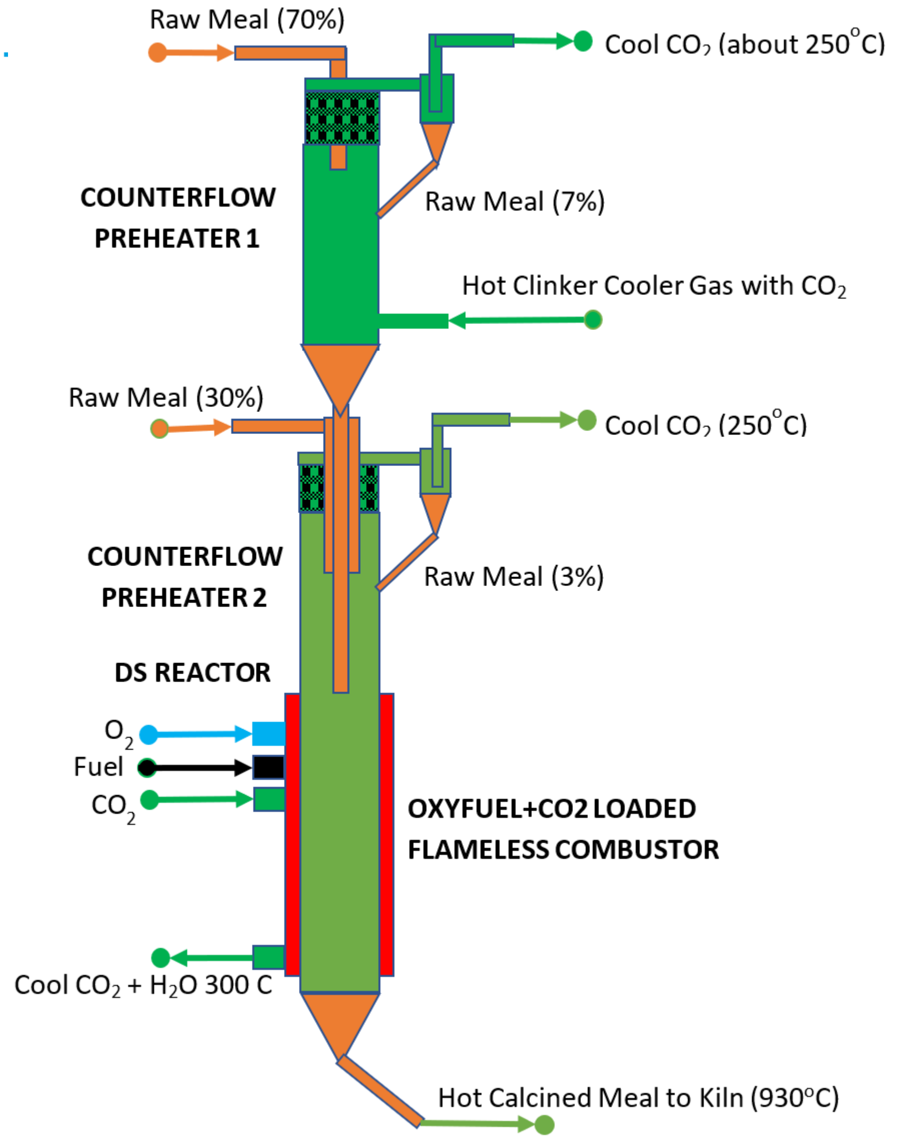


LEILAC Pilot Plant is located at CBR Lixhe, Belgium

Site of the LEILAC pilot plant

INTEGRATION OF DIRECT SEPARATION INTO CEMENT PRODUCTION

A CALIX PERSPECTIVE



Not to Scale

Follow LEILAC's progress…

www.project-leilac.eu

Follow us on twitter: @ProjectLEILAC